

# **SOIL MONITORING DIRECTIVE**

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Soil Monitoring Directive 2009

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## PREFACE

Alberta Environment (AENV) established a Soil Monitoring Program and a Soil Management Program through the *Guideline for Monitoring and Management of Soil Contamination under EPEA Approvals* (AENV, 1996a) and the *Soil Monitoring Directive* (AENV, 1996b). These programs were designed to protect soil, prevent cross-media transfer of contaminants, and reduce the risk associated with contaminant releases to the soil on facilities approved by AENV. Both documents have been referred to extensively as regulatory tools for monitoring and managing soil contamination in Alberta for more than 10 years.

This document amends the 1996 *Soil Monitoring Directive* and incorporates the *Guideline for Monitoring and Management of Soil Contamination under EPEA Approvals*. The two 1996 documents are no longer in effect.

This document includes reference to relevant recent policy initiatives for assessment and remediation of contaminated sites including *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AENV, 2009a), *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (AENV, 2009b), and the *Record of Site Condition* (AENV, 2009c).

Clear regulatory requirements and professional guidance can be found with this revised Directive. It will help the Ministry to meet its regulatory mandate and provide better regulatory directions to approval holders and environmental professionals for the protection of our land and water resources.

### Contact information regarding this document

This document will continue to be updated from time to time as new knowledge or improved environmental practice becomes established. Suggestions and comments for future revision to this document may be directed to:

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## INTRODUCTION

Risk for soil contamination exists at industrial plants that have a potential for release of substances to the environment. Soil contamination may also become a source of contamination for groundwater, surface water and air. Remediation costs often increase sharply when soil contamination spreads to other media. Regulatory requirements and professional guidance are needed to ensure that the soil resource and associated environmental media are protected at industrial sites.

### Regulatory Purpose

Alberta Environment (AENV) established a Soil Monitoring and a Soil Management Program for industrial plants through the *Guideline for Monitoring and Management of Soil Contamination under EPEA Approvals* (AENV, 1996a) and *Soil Monitoring Directive* (AENV, 1996b). This revised Directive incorporates the former and amends the latter.

Baseline soil monitoring, pro-active operational soil monitoring, and timely management of contaminated soils are recognized environmental approaches to protect soil and related media. The revised Directive outlines regulatory requirements and professional guidance needed to conduct the Baseline Soil Monitoring, Operational Soil Monitoring and Soil Management Programs when those programs are required by an approval issued under the *Environmental Protection and Enhancement Act* (EPEA). Other regulatory requirements related to release of substances and remediation are found in EPEA and associated regulations.

The objectives of this Directive are to:

- a) identify sources of substance releases from approved plants in Alberta before they result in significant contamination to the soil resource;
- b) ensure timely actions are taken to eliminate or control the sources of soil contamination and prevent or reduce the risk of contaminant transfer from impacted soils to other environmental media (air or water) or potential receptors; and
- c) ensure timely assessment, management and reporting of all contaminated areas associated with approved plants and reduce the environmental impact associated with industry approvals in Alberta.

### Structure of the Directive

This Directive is comprised of three major sections:

- a) Baseline Soil Monitoring Program;
- b) Operational Soil Monitoring Program; and
- c) Soil Management Program.

The Baseline Soil Monitoring Program is intended to characterize the soil prior to the commencement of plant operations. The main objective of the Operational Soil Monitoring Program is to screen for soil contamination from substances with the potential to exert adverse effects on soil and interconnected media. The Soil Management Program is intended to remediate contaminated soil, and mitigate or eliminate the adverse effects to human health and the environment.

## Requirements for Assessment, Monitoring and Management

The Directive provides both guidance and requirements for conducting the three soil programs. *Those provisions that are specifically linked to the approval and intended to be enforceable are written in italics with numbered clauses in this Directive.* The following language format has been adopted to reflect the intended purposes for development of the proposals and reports for the foregoing programs:

- a) **shall** or **must**: denotes a requirement in the Directive; and
- b) **should** or **may**: refers to guidance or a recommendation.

## Application of this Directive to Site-Specific Issues

This Directive is not a stand-alone regulatory document. It is meant to be used in conjunction with Alberta's existing regulatory framework as outlined in EPEA and relevant regulations, standards and guidelines such as *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AENV, 2009a) as amended, *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (AENV, 2009b) as amended, and individual EPEA approvals.

As the document is largely designed to provide general regulatory requirements and professional guidance at a provincial level, it is out of the scope of this document to address various site-specific issues such as field safety issues to personnel and plant operation. Alberta Environment expects approval holders and their environmental consultants to exercise sound professional judgements and due diligence when they plan and execute any program in this Directive. Communication with the relevant AENV regional staff members, who oversee the industrial plant, will ensure that site-specific solutions are found for site-specific issues.

While this Directive is developed for industrial approvals, the principles contained within this Directive may be applied to other industrial facilities when referred to by the Department.



## 1. BASELINE SOIL MONITORING PROGRAM

The Baseline Soil Monitoring Program is designed for approval holders that are commencing operations on new facilities or expanding operations to new locations. The purpose of the Baseline Soil Monitoring Program is to provide a data set that describes the soil conditions before the commencement of plant operation. It aids in detection of subsequent release of substances to the soil during operation of the plant and in setting assessment or remediation targets for Operational Soil Monitoring, Soil Management, or facility decommissioning.

### 1.1. Program Design for Baseline Soil Monitoring

#### 1.1.1. Soil Sampling

- 1.1.1.1. Prior to the commencement of plant operation, the approval holder for a new plant or plant expansion must conduct the Baseline Soil Monitoring Program on areas developed or being developed for operational activity.*
- 1.1.1.2. The approval holder for a new plant or plant expansion shall ensure that the major soil strata where disturbances are planned or occurred are characterized.*
- 1.1.1.3. The approval holder for a new plant or plant expansion shall conduct baseline soil sampling in the following manner:*
  - a) soil samples must be obtained from the footprint areas of the plant;*
  - b) in selecting baseline soil sampling locations, the approval holder shall give preference to sampling locations where the potential of future release of substances to soil and groundwater is most likely to occur;*
  - c) any fill materials must be analyzed to prevent contamination from off-site sources;*
  - d) where the surficial geology and landscape is reasonably uniform and the developed area on the site is small (<4 hectares), soil samples must be obtained from a minimum of four locations from the proposed footprint areas for the plant site;*
  - e) where surficial geology and landscape have significant variability, soil samples must be collected from locations of all major soil mapping units to allow adequate characterization of site variability for soil at the proposed footprint areas of the plant; and*
  - f) for areas where soil disturbance is planned for below ground infrastructure (e.g. underground storage tanks) that has a potential for release of substances, soil sampling must extend to a depth below the base of the proposed infrastructure.*

Soil samples must be taken in such a manner that changes in concentrations with depth for chemicals of potential environmental concern are sufficiently delineated. Default depth-increments should be:

- a) 0 to 15 cm;
- b) 15 to 30 cm;
- c) 30 to 60 cm;
- d) 60 to 100 cm; and
- e) in 50-cm increments thereafter to the depth of disturbance.



Where there are apparent changes in soil lithology or presence of visible contamination in the soils, it may be necessary to alter the default soil sampling depths to reflect site conditions.

For operating plants that have not conducted the Baseline Soil Monitoring Program prior to commencement of operation, the approval holder should refer to Section 2.1.1 for further information.

### 1.1.2. Analytical Parameters

*1.1.2.1. The approval holder shall analyze each soil sample for all of the following:*

- a) pH using the 0.01 M CaCl<sub>2</sub> method;*
- b) electrical conductivity (EC) using the saturated paste method;*
- c) cation exchange capacity (CEC);*
- d) organic carbon content;*
- e) texture (percent sand, silt and clay);*
- f) median of particle size above 75 µm;*
- g) sodium adsorption ratio (SAR);*
- h) total trace element content by strong acid digestion; and*
- i) baseline concentrations for chemicals corresponding to facility-specific substances that typically have measurable background concentrations in the soil and as defined in Section 2.1.4 of this Directive.*

For an undeveloped site where the baseline soil condition for a soil parameter is suspected to be affected by any regional or local geochemical abnormality, that parameter should be included for analysis. In particular, the Baseline Soil Monitoring Program should include any parameter where the background condition may exceed the *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AENV 2009a) as amended. For example, analyses of soil soluble sodium or sulphate should be included at a site where geochemical enrichment of those elements is expected as the result of natural groundwater discharge.

### 1.1.3. Sample Handling

*1.1.3.1. The approval holder shall use procedures that avoid cross-contamination of samples and degradation and loss of substances when*

- (a) collecting,*
- (b) handling,*
- (c) storing,*
- (d) transporting, and*
- (e) analyzing soil samples.*

### 1.1.4. Laboratory Analysis Requirement

*1.1.4.1. The approval holder shall analyze all required samples in a laboratory accredited pursuant to ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories, as amended or replaced from time to time, for the specific parameter(s) to be analyzed, unless otherwise authorized in writing by the Director.*

- 1.1.4.2. *The approval holder shall ensure that the laboratory uses standard methods developed, adopted or authorized by AENV.*

## **1.2. Requirements for Baseline Soil Monitoring Program Report**

- 1.2.1.1. *The approval holder for a new plant or plant expansion to non-commercial and non-industrial areas shall submit a Baseline Soil Monitoring Program report to the Director that contains all of the following information:*

### ***Administrative information***

- a) *clear identification of Baseline Soil Monitoring Program report in title of the report;*
- b) *the business name of the approval holder of the plant;*
- c) *the name and location of the plant;*
- d) *date of report;*
- e) *the name of the environmental consulting firm and signature(s) of the environmental professional(s);*

### ***Regional and site characteristics***

- f) *a map and description of the site, including but not limited to legal location, topography, surface drainage, parent geological materials, soil types, vegetation, depth to groundwater, groundwater flow direction, adjacent surface water bodies and major land use prior to site disturbance;*
- g) *a detailed site plan, or photo mosaic or aerial photograph with a 1:5000 scale or finer resolution with illustration of the proposed locations for major facility areas including waste handling areas and relevant surface features;*

### ***Chemicals of potential environmental concern***

- h) *a short description of processes and activities to be carried out at the plant and associated chemicals of potential environmental concern;*
- i) *a description of known and reported historical release, if any;*

### ***Sampling and analysis***

- j) *a site plan, or photo mosaic or aerial photograph at 1:5000 scale or finer resolution indicating soil sampling locations;*
- k) *a table identifying sampling locations and procedures, and analytical parameters for each sampling location;*
- l) *the rationale for choosing the sampling procedures and depth-increments, when they differ from those specified in Section 1.1.1;*
- m) *a description of the field quality assurance and quality control (QA/QC) procedures followed for collecting, handling, storing and transporting soil samples;*
- n) *the rationale for using the laboratory analytical methods and a description of relevant laboratory quality control (QC) procedures;*

### ***Results and discussion***

- o) *tables presenting all analytical results for all sampling locations, highlighting values, if any, that are greater than Alberta Tier 1 Soil and Groundwater Remediation Guidelines (AENV, 2009a) as amended;*

- p) a discussion of all analytical results as compared with Alberta Tier 1 Soil and Groundwater Remediation Guidelines (AENV, 2009a) as amended, or other standards as outlined in Section 2.1.6;*
- q) an evaluation and interpretation of all analytical results against local soil survey results, any regional or local geochemical abnormality and historical release;*
- r) any other information as requested in writing by the Director;*

#### **Appendices**

- s) borehole logs where a sampling location is drilled;*
- t) soil logs for testpit or hand auger sampling locations; and*
- u) a copy of laboratory data sheets.*

### **1.3. New Construction or Plant Expansion on Potentially Contaminated Sites**

Existing commercial or industrial sites may have a higher probability of soil contamination from release of substances associated with the existing or historical use of the site. It is to the benefit of the approval holder to understand the environmental conditions and potential liability associated with such sites. Thorough site assessment and remediation prior to construction is the best approach to understanding and reducing the potential for ongoing contaminant liability. Therefore, the approval holder will need to understand the existing conditions on the site, either through up to date environmental information, or by carrying out a thorough environmental site assessment before construction occurs.

While some general direction is provided here, it is beyond the scope of this Directive to define specific requirements for such site assessments. More comprehensive environmental site assessment guidance may be found in the following documents:

- a) Phase I Environmental Site Assessment, Z768-01 (CSA, 2001), as amended;*
- b) Phase II Environmental Site Assessment, Z769-00 (CSA International, 2000), as amended;*  
*and*
- c) Any relevant additional guidance that is available from AENV for conducting environmental site assessments.*

If the environmental site assessment reveals soil contamination, the approval holder will need to conduct soil remediation or risk management prior to site construction. In particular, the approval holder will need to address portions of the plant site where construction will be on top of, or otherwise affect, areas with contamination. If there is residual contamination left at the plant site, the approval holder will likely need to develop a Soil Management Program as outlined in Section 3.

Background soil conditions should reflect the natural soil conditions prior to disturbance for commercial or industrial development. Therefore, it may be difficult to find suitable background locations at previously impacted sites. Care should be taken to select appropriate background locations in soil assessment. Further information on background samples is provided in Section 2.1.1 of this Directive.

Good communication with AENV's regional staff can help to find site-specific solutions for site-specific issues.

## 2. OPERATIONAL SOIL MONITORING PROGRAM

Operational Soil Monitoring refers to soil monitoring activities for an operating plant. The following guidance and requirements are developed for this program.

### 2.1. Program Design for Operational Soil Monitoring

The Operational Soil Monitoring Program is intended to screen for release of substances to soil from the operation and activities of a plant. The program must be designed to identify the most likely locations for release of substances. Soil samples must be collected as near as possible to these locations without compromising safety standards.

Before developing the Operational Soil Monitoring Program, the approval holder must review all existing documents (e.g., company files, reports, letters and environmental site assessment records) relevant to potential releases to soil, conduct interviews with staff knowledgeable about the history of the operation and any spills and other releases, and conduct a site visit to identify areas of known and potential soil contamination. The information should be used to plan the Operational Soil Monitoring Program.

#### 2.1.1. Background Samples

A contaminant is a substance that is present in an environment medium in excess of the natural background concentration (CCME, 2006). Background soil samples are collected and analyzed to determine the natural background concentration. This information, in turn, can be used to detect release of substances and where needed, in defining site-specific remediation objectives.

For the first Operational Soil Monitoring event, a sufficient number of background samples must be collected to account for site variability. Background samples should be collected from sites that are not affected by the plant operation but are from comparable landscape locations, in close proximity to the site of interest and have similar soil properties to on-site locations. Where it is impossible to collect valid on-site background samples, off-site background sampling should be considered.

*2.1.1.1. The approval holder shall collect background samples in the following manner:*

- a) where a Baseline Soil Monitoring Program has not been completed, soil samples must be collected from a minimum of four background locations during the first Operational Soil Monitoring Program;*
- b) where a Baseline Soil Monitoring Program was completed, soil samples must be collected from at least two background locations during the first Operational Soil Monitoring Program; and*
- c) background samples must be collected from locations that are free from operational impact and have similar soil to that found on the site.*

*2.1.1.2. The approval holder shall conduct soil analysis in the following manner:*

- a) where a Baseline Soil Monitoring Program has not been completed at the plant site, the soil samples shall be analysed for the soil properties outlined in Section 1.1.2; and*
- b) where a Baseline Soil Monitoring Program has been completed at the plant site, the soil samples shall be analysed for the properties outlined in Section 2.1.5.*

### 2.1.2. Samples for Facility Areas and Sampling Locations

The requirement for Operational Soil Monitoring is based on the potential risks for release of substances. Where the risk of soil contamination is minimal because of the kind of operation taking place at a specific location or because engineered controls are in place to protect soil, part of the plant areas may be exempted from Operational Soil Monitoring. The lack of risk needs to be clearly established prior to exempting any facility area within a plant. For example, use of impermeable secondary containment along with inspection records and reports that ensure against leaks may provide a basis for exemption. In contrast, the use of engineered earthen barriers, inadequate maintenance of secondary containment, absence of inspection records or clean-up records of any spill, may preclude the exemption.

#### 2.1.2.1. *Soil samples shall be collected at locations of:*

- a) *known soil contamination;*
- b) *known releases of contaminants of potential concern to soil or groundwater; and,*
- c) *potential soil contamination, including but not limited to the following:*
  - i) *areas for storage of product, raw material, treatment chemical, catalyst or waste;*
  - ii) *near process areas;*
  - iii) *chemical loading and unloading facilities, including loading docks;*
  - iv) *storage areas such as boneyards or warehouses for new and out of service equipment (including but not limited to transformers, vehicles and compressors) that may be a source of soil contamination;*
  - v) *machinery servicing and maintenance areas;*
  - vi) *washing areas for equipment (including but not limited to containers, tanks, filters and vehicles);*
  - vii) *near underground sumps, tanks and pipelines;*
  - viii) *any off-site areas that may have been impacted by activities that have occurred on-site, whether planned (e.g., wastewater irrigation) or unplanned (e.g., spills);*
  - ix) *near unlined drainage ditches;*
  - x) *low-lying areas that may be affected by surface run-off;*
  - xi) *above-ground chemical pipe racks;*
  - xii) *near oil production and disposal wells; and*
  - xiii) *any other areas where contamination may occur.*

Where it is authorized by the Director, the approval holder may choose to exempt sampling locations described under a) and b) of Section 2.1.2.1 if the location has been completely delineated as defined in the *Alberta Tier 1 Soil and Groundwater Quality Guidelines* (AENV, 2009a) as amended, and

- a) the location meets all acceptable soil or groundwater quality guidelines as defined in Section 2.1.6; or
- b) the location is currently being managed under a Soil Management Program as defined in Section 3 of the Directive.

### 2.1.3. Sampling Methods

Soil samples must be collected in such a manner that ensures changes in contaminant concentration with depth are delineated. Soil samples should be properly screened in the field to determine the most likely zones of contamination.



In general, soil samples should be collected using discrete sampling. When sampling for volatile and semi-volatile substances, discrete samples must be collected to avoid changes in contaminant concentration during sampling. Care should be taken to define the most likely locations for soil contamination and sampling at these locations. In some instances where an initial screening is being conducted for contaminants that are not readily identifiable in the field and where the most likely locations of release cannot be defined, a composite sampling strategy may be considered. For instance, it may be preferable to use a composite sampling strategy for initial screening along a drainage channel.

If the area to be sampled is small and clearly defined, soil samples may be taken from a single location within the defined area. To investigate less defined areas where there are no apparent substrata or where contamination cannot be readily identified in the field, more discrete samples are often required to establish site variability. Further information on sampling designs can be found elsewhere (e.g. Gilbert, 1987; Crépin and Johnson, 1993; and Pennock et al., 2008).

Soil samples should be collected from all the following depth-increments at each sampling location:

- a) 0 to 15 cm;
- b) 15 to 30 cm;
- c) 30 to 60 cm;
- d) 60 to 100 cm;
- e) if contamination extends below 100 cm, in 50-cm increments until one increment below the maximum depth of contamination, as proof of delineation;
- f) where there is potential for release of substance from infrastructure below ground (e.g. storage tanks and pipelines), depth-increments should be chosen to allow determination of the most likely zone of contamination even below the base of the infrastructure; and
- g) for locations associated with a spill or potential release of particular contaminants that may be degraded easily under aerobic conditions but slowly in subsurface conditions, boreholes should be extended to a sufficient depth to screen against the potential contamination at deeper depths, including subsurface.

*2.1.3.1. The approval holder shall follow:*

- a) *the soil handling requirements as outlined in Section 1.1.3; and*
- b) *the laboratory accreditation requirements and analytic methods in accordance with Section 1.1.4 of this Directive.*

*2.1.3.2. The approval holder shall conduct the*

- a) *collection,*
- b) *handling,*
- c) *storage,*
- d) *transportation, and*
- e) *analysis*

*of soil samples in accordance with the following, unless otherwise authorized in writing by the Director:*

- i) *Soil Sampling and Methods of Analysis (Carter, 1993), Lewis Publishers, as amended or replaced from time to time;*

- ii) *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* (United States Environmental Protection Agency, 1986), as amended or replaced from time to time;
- iii) *Guidance Manual on Sampling, Analysis and Data Management for Contaminated Sites – Volume I: Main Report*, EPC-NCS62E (CCME, 1993a), as amended or replaced from time to time;
- iv) *Guidance Manual on Sampling, Analysis and Data Management for Contaminated Sites – Volume II: Analytical Method Summaries*, EPC-NCS66E (CCME, 1993b), as amended or replaced from time to time; or
- v) *Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soils: Scientific Rationale* (CCME, 2008), as amended or replaced from time to time.

#### 2.1.4. Facility-Specific Substances

2.1.4.1. *The approval holder shall analyze all facility-specific substances associated with the operation.*

Facility-specific substances are those that may be present as a result of operation of the plant. The approval holder must review past and current operations to develop a list of facility-specific substances. The *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AENV, 2009a), as amended, can be referred to for a listing of contaminants that could be considered as facility-specific substances. Examples of facility-specific substances include but are not limited to the following:

- a) strong acid digestible trace elements such as barium, cadmium, chromium (total and hexavalent), cobalt, copper, lead, mercury, molybdenum, nickel, selenium, vanadium, and zinc;
- b) inorganics such as arsenic, boron (hot water extractable), cyanide, and sulphur;
- c) salts such as sodium chloride;
- d) hydrocarbons such as benzene, ethylbenzene, toluene, and xylenes (BTEX), polycyclic aromatics, fractions F1, F2, F3 and F4 of petroleum hydrocarbons;
- e) process chemicals such as methanol, ethanol, sulfolane, glycols, and amines;
- f) halogenated organics such as brominated or chlorinated sterilants, dioxins and furans, chlorobenzenes, chlorophenols, polychlorinated biphenyls, perchloroethylene and vinyl chloride; and
- g) any toxic organic precursors, intermediates, products, by-products, additives, catalysts or wastes.

#### 2.1.5. Analytical Requirements

2.1.5.1. *The approval holder shall analyze soil samples collected during Operational Soil Monitoring for:*

- a) *pH using the 0.01 M CaCl<sub>2</sub> method; and*
- b) *electrical conductivity with the saturated paste method.*

2.1.5.2. *The approval holder shall analyze soil samples to provide vertical delineation for:*

- a) *relevant facility-specific substances;*
- b) *any substance that has exceeded and may still exceed the applicable soil quality standards; and*



- c) any parameter as requested in writing by the Director.*

Note that the soil quality standards are often tied to the soil texture. Therefore, where soil texture data are not available it is advisable to collect soil texture information during Operational Soil Monitoring. If the soil texture is unknown or questionable, the most conservative soil texture guideline is assumed to apply to the site.

### **2.1.6. Soil Quality Standards**

As a participant in CCME, AENV advocates remediation to the lowest concentration possible. AENV encourages responsible environmental practice and does not accept the action of polluting up to a limit (AENV, 2009a). If Operational Soil Monitoring detects cumulative release of substances, mitigative measures must be taken including, at a minimum, source control even when a contaminant concentration is below an applicable soil quality standard.

Reports shall always include, as a minimum, comparison against background data and targeted remediation values in *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AENV, 2009a), as amended, regardless of whether site-specific remediation values are developed. The Alberta Tier 1 values for comparison must reflect both the current land use and end land use. In addition, this Directive requires monitoring for all facility-specific substances that may pose a risk to the environment or human health, regardless of whether soil quality standards exist for those substances.

Soil quality standards should be either applicable generic standards or site-specific standards. Where the current land use and end land use are different, the most conservative standard is the applicable standard. Standards must be determined in accordance with the following sections.

#### **Generic Soil Quality Standards**

- 2.1.6.1. The approval holder shall use the following generic soil quality standards:*
- a) applicable generic soil quality standards from Alberta Tier 1 Soil and Groundwater Remediation Guidelines (AENV, 2009a), as amended; or*
  - b) other generic guideline values adopted by AENV or specified in writing by the Director.*

#### **Site-Specific Soil Quality Standards**

- 2.1.6.2. Where a soil is contaminated by a substance that is not listed in the generic standards in Section 2.1.6.1, the approval holder shall derive a site-specific soil quality standard for the substance.*
- 2.1.6.3. Where the generic standards in Section 2.1.6.1 are not applicable to a specific plant site, the approval holder shall derive site-specific soil quality standards for the substance(s).*
- 2.1.6.4. The approval holder shall obtain authorization in writing from the Director for site-specific soil quality standards derived under Sections 2.1.6.2 or 2.1.6.3 of this Directive prior to use.*

2.1.6.5. *A proposed site-specific soil quality standard for a given substance shall be determined in accordance with the following:*

- a) the natural background concentration of the substance;*
- b) Alberta Tier 2 Soil and Groundwater Remediation Guidelines (AENV, 2009b), as amended;*
- c) a criterion developed using site-specific risk assessment techniques for human health and ecological receptors consistent with Alberta Tier 2 Soil and Groundwater Remediation Guidelines (AENV, 2009b), as amended; or*
- d) a criterion derived using A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines (CCME, 2006); as amended or replaced from time to time.*

Both current and end land use situations must be considered while developing site-specific standards. Communication with AENV is important at all stages of risk assessment. Additional resource information is available in the following documents and websites:

- a) Alberta Tier 2 Soil and Groundwater Remediation Guidelines (AENV, 2009b), as amended;*
- b) A Framework for Ecological Risk Assessment: General Guidance (CCME, 1996), as amended or replaced from time to time;*
- c) Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (Health Canada, 2004), as amended or replaced from time to time;*
- d) A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines (CCME, 2006), as amended or replaced from time to time;*
- e) Guidelines available at website of United States Department of Energy Risk Assessment Information System (RAIS) (<http://rais.ornl.gov/>); and*
- f) Guidelines available at website of United States Environmental Protection Agency Integrated Risk Information System (IRIS) ([www.epa.gov/iris](http://www.epa.gov/iris)).*

## **2.2. Requirements for Operational Soil Monitoring Program Proposal**

2.2.1.1. *The Operational Soil Monitoring Program proposal shall contain, at a minimum, all of the following information:*

### ***Administrative information***

- a) clear identification of Operational Soil Monitoring Program proposal in title of the document;*
- b) the business name of the approval holder;*
- c) the name and location of the plant;*
- d) date of the proposal;*
- e) the name of the environmental consulting firm and the signature(s) of the environmental professional(s);*

### ***Regional and site characteristics***

- f) a description and map at the appropriate scale indicating the regional setting, including but not limited to topography, surficial geology, soil types, vegetation, water bodies and major land use;*

- g) *a description of the site, including but not limited to topography, surface drainage, parent geological materials, soil types, fill material, vegetation, depth to groundwater and groundwater flow direction, adjacent water bodies and land use;*
- h) *a detailed site plan, photo mosaic or aerial photograph with a 1:5000 scale or finer resolution indicating major facility areas including waste handling areas and relevant surface features;*

***Release of substance***

- i) *a short description of processes and activities carried out at the plant and associated substances of concern;*
- j) *a short description of any change to infrastructure and operation since the last soil monitoring and management events, if any;*
- k) *a description of known and reported historical releases, including locations and the status of any subsequent environmental site assessment and remediation;*
- l) *a map clearly indicating historical releases and contamination that has been delineated;*

***Proposed soil sampling and analysis***

- m) *a detailed site plan, photo mosaic or aerial photograph at 1:5000 scale or finer resolution indicating former and proposed soil sampling locations, including background samples;*
- n) *a table identifying facility areas, rationale for selection of the proposed sampling locations, methods and analytical parameters for each sampling location;*
- o) *the rationale for choosing the proposed sampling procedures and depth-increments, when they differ from those specified in Section 2.1.3;*
- p) *a brief description of field QA/QC procedures to be followed for collecting, handling, storing and transporting soil samples during the program;*
- q) *the rationale for using the analytical methods and a description of relevant laboratory QC procedures; and*
- r) *any other information as requested in writing by the Director;*

***Proposed schedule and soil quality standards***

- s) *the proposed schedule for the collection of soil samples; and*
- t) *proposed generic soil quality standards, developed in accordance with Section 2.1.6.1, for each substance that is known or likely to be on-site and off-site.*

**2.3. Requirements for Operational Soil Monitoring Program Report**

2.3.1.1. *The Operational Soil Monitoring Program report shall contain, at a minimum, all the following information:*

***Administrative information***

- a) *clear identification of Operational Soil Monitoring Program report in title of the report;*
- b) *the business name of the approval holder;*
- c) *the name and location of the plant;*
- d) *date of report;*

- e) *the name of the environmental consulting firm and the signature(s) of the environmental professional(s);*

***Regional and site characteristics***

- f) *description and map at the appropriate scale indicating the regional setting, including but not limited to legal location, topography, surficial geology, soil types, vegetation, water bodies and major land use;*
- g) *a description of the site, including but not limited to topography, surface drainage, parent geological materials, soil types, fill material, vegetation, depth to groundwater, groundwater flow direction, adjacent water bodies and land use;*
- h) *a detailed site plan, or photo mosaic or aerial photograph with a 1:5000 scale or finer resolution indicating major facility areas including waste handling areas and relevant surface features;*

***Release of substance***

- i) *a short description of processes and activities carried out at the plant and associated substances of concern;*
- j) *a short description of any change to infrastructure and operation since the last soil monitoring and management events, if any;*
- k) *a description of known and reported historical releases, including locations and the status of any subsequent environmental site assessment and remediation;*

***Sampling and analysis***

- l) *a detailed site plan, or photo mosaic or aerial photograph at 1:5000 scale or finer resolution indicating former and current soil sampling locations, including background samples;*
- m) *a table identifying facility areas, rationale for selection of current sampling locations and procedures, and analytical parameters for each sampling location;*
- n) *the rationale for choosing the sampling procedures and depth-increments, when they differ from those specified in Section 2.1.3;*
- o) *a description of field QA/QC procedures followed for collecting, handling, storing and transporting soil samples during the program;*
- p) *the rationale for using the analytical methods and a description of relevant laboratory QC procedures;*

***Results and discussion***

- q) *tables presenting all analytical results for all sampling locations, highlighting values that are greater than Alberta Tier 1 Soil and Groundwater Remediation Guidelines (AENV, 2009a) as amended, and any applicable soil quality standard specified in Section 2.1.6;*
- r) *a table summarizing analytical results for those sampling locations where values are greater than applicable soil quality standards specified in Section 2.1.6;*
- s) *a detailed site plan, or photo mosaic or aerial photograph at 1:5000 scale or finer resolution indicating sampling locations where substances of concern exceed any applicable soil quality standards;*
- t) *a discussion of analytical results as compared with those of baseline/background samples and applicable soil quality standards;*

- u) an evaluation and interpretation of all analytical results;*
- v) recommendations whether a Soil Management Program proposal is needed or a proposal is forthcoming to address the exceedance; and*
- w) any other information as requested in writing by the Director;*

***Appendices***

- x) borehole logs where a sampling location is drilled;*
- y) soil logs for testpit or hand auger sampling locations;*
- z) a copy of laboratory data sheets; and*
- aa) a duly completed and signed form of 'Record of Site Condition'.*

Examples of appropriate tables are provided in Appendix A for reference.



### 3. SOIL MANAGEMENT PROGRAM

The Soil Management Program is intended to manage and remediate contaminated soils. To this end, it must mitigate or eliminate adverse effects to human health and the environment. Given the release of substances to soil, it must also prevent their transport from soil to groundwater, surface water or air. Source control and preventing further release of substances to soil, groundwater, surface water or air, are of paramount importance.

An approval holder needs to develop and implement a Soil Management Program in accordance with the conditions set out in this Directive and the approval. Section 3.1 provides guidance for developing the Soil Management Program when a soil contaminant is found at a concentration that exceeds any applicable soil quality standard specified in Section 2.1.6. Sections 3.2 and 3.3 provide specific requirements for the Soil Management Program proposal and report respectively.

#### 3.1. Guidance for Development of Soil Management Program

##### 3.1.1. Overview of Soil Management Process

The Soil Management Program must first identify, remove or control active sources and stop any ongoing release of substances. Thereafter, further assessment and delineation of the affected area are necessary. Discrete sampling must be conducted to properly delineate the extent of contamination. Following delineation, the approval holder should develop a conceptual site model to understand the situation. Then, remediation objectives for the affected area should be defined. Appropriate treatment or containment technologies should be chosen to meet the remediation objectives. The Soil Management Program must provide a schedule for its implementation and follow the regulatory reporting timelines as outlined in the approval. The program needs to demonstrate progress towards meeting the remediation objectives. The overall Soil Management Program plan must be authorized by the Director for implementation. The *Record of Site Condition* form is designed to help approval holders to track the progress of the program.

##### 3.1.2. Remediation Objectives for Soil Management Program

A Soil Management Program must follow the principles of contaminant management as outlined in the *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AENV, 2009a), as amended. Depending on the site, remediation objectives for the Soil Management Program may be developed by adopting generic soil quality standards or using a site-specific risk assessment. The generic soil quality standards or site-specific risk assessment procedures as listed in Section 2.1.6 are applicable for setting remediation targets and evaluating outcomes of a Soil Management Program.

Some site conditions where generic values may not be applicable have been identified in *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AENV, 2009a). These include contamination within 30 cm of building foundation, unusual building features like an earthen floor, fractured bedrock, contamination within 10 m distance to a surface water body, and potentially high hydraulic conductivity of soils ( $>10^{-5}$  m/sec). For these conditions, it may be necessary to consider a Tier 2 approach to determine an appropriate risk-based remediation requirement. The approval holders should consult *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (AENV, 2009b) as amended, for further information.

When the site conditions exclude application of generic soil quality standards or there is no soil quality standard for a particular substance at a plant site, the following three options may be considered:

- a) remediation objectives may be derived based on the natural background conditions for the site, in a manner consistent with *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (AENV, 2009b) as amended;
- b) site-specific remediation objectives may be adopted from another jurisdiction if those remediation objectives are demonstrated to be consistent with the environmental protection goals of this Directive and acceptable to the Director; or
- c) remediation objectives may be developed by using the site-specific risk assessment procedures.

Site-specific risk assessment is a means to quantify the likelihood that soil contamination will have an adverse effect under conditions found at a specific site. It generally involves the following components:

- a) problem formulation with a conceptual site model;
- b) exposure assessment by examination of pathway and receptor relationship;
- c) toxicity assessment to examine the dose/response relationship; and
- d) risk characterization by investigating the overall relationship of source, pathway and receptors.

Because of the nature of site-specific risk assessments, remediation objectives developed in this manner will require authorization in writing by the Director.

### 3.1.3. Exposure Control

Where it is not possible to remediate a site to meet the soil quality standards in Section 2.1.6, the approval holder must develop an appropriate risk management plan as part of the Soil Management Program for authorization in writing by the Director. For exposure control to be authorized, the approval holder must ensure that the contaminants are contained and receptor exposure does not occur. Formal risk assessment, exposure control and risk management procedures are necessary to meet these requirements. Interaction with AENV is important at all stages of the process. However, the approval holder bears responsibility for the design, construction, assessment and maintenance of the risk management system and any necessary emergency response, should the system fail.

For further information, the approval holder should consult specific resource information on risk assessments, exposure control and risk management, including those provided in Section 2.1.6 of this Directive.

Regardless of the approach that is used to address the Soil Management Program while the plant is still operating, plant decommissioning must include remediation objectives that are tailored to meet the soil and groundwater quality standards for appropriate end land use. Where multiple types of land use occur, the soil and groundwater quality standards must be tailored to meet the most stringent land use.



### 3.2. Requirements for Soil Management Program Proposal

3.2.1.1. *The Soil Management Program Proposal shall contain, at a minimum, all of the following information:*

#### **Administrative information**

- a) *clear identification of Soil Management Program proposal in the title of the document;*
- b) *the business name of the approval holder;*
- c) *the name and location of the plant;*
- d) *date of the proposal;*
- e) *the name of the environmental consulting firm and signature(s) of the environmental professional(s);*

#### **Regional and site characteristics**

- f) *a brief description and map at the appropriate scale indicating the regional setting, including but not limited to topography, surficial geology, soil types, vegetation, water bodies and major land use;*
- g) *a brief description of the site, including but not limited to topography, surface drainage, parent geological materials, soil types, fill material, vegetation, depth to groundwater, groundwater flow direction, adjacent water bodies and land use;*
- h) *a detailed site plan, or photo mosaic, or aerial photograph with a 1:5000 scale or finer resolution, indicating major facility areas including waste handling areas and relevant surface features;*
- i) *a table presenting all analytical results from previous Operational Soil Monitoring or other monitoring event(s), for those sampling locations where values are greater than applicable standards specified in Section 2.1.6;*
- j) *a summary of all remedial actions taken to date to remove, remediate or control any source for any substances of concern exceeding the applicable standards at the site;*

#### **Proposed soil sampling and analysis**

- k) *a detailed site plan, or photo mosaic, or aerial photograph at 1:5000 scale or finer resolution indicating proposed and previous sampling locations and identifying analytical parameters where values exceed any applicable standard from previous Operational Soil Monitoring or other monitoring and remediation event(s), if any;*
- l) *where soil contamination is likely to impact or has already impacted groundwater or surface water quality; a map showing groundwater flow patterns (including contour maps) and sampling locations, and identifying soil and groundwater analytical parameters exceeding the applicable standards;*
- m) *a plan to delineate the horizontal and vertical extent of contamination within each contaminated area, depending on the stage of the Soil Management Program;*

#### **Proposed soil assessment and soil management plans**

- n) *proposed soil quality standards developed in accordance with Section 2.1.6 of this Directive, for each substance that is known or likely to be present;*
- o) *rationale for using each of the proposed soil quality standards;*
- p) *clearly justified remediation objectives if they are different from the soil and groundwater quality standards for the end land use for the site;*

- q) *a detailed action plan to further remove, remediate or control all sources of contamination and residual contamination;*
- r) *an appropriate risk management plan where infrastructure or ongoing operations prevent soil sampling and delineation or remediation;*
- s) *a yearly schedule of all soil management activities proposed to achieve remediation objectives for each affected facility area;*
- t) *a plan for handling and disposal of the substance(s) that may be released into the environment as a result of conduct of the Soil Management Program; and*
- u) *any other information as requested in writing by the Director.*

### **3.3. Requirements for Soil Management Program Report**

3.3.1.1. *The Soil Management Program report shall contain, at a minimum, all of the following information:*

#### ***Administrative information***

- a) *clear identification of Soil Management Program report in title of the report;*
- b) *the business name of the approval holder;*
- c) *the name and location of the plant;*
- d) *date of report;*
- e) *the name of the environmental consulting firm and signature(s) of the environmental professional(s);*

#### ***Regional and site characteristics***

- f) *a description and map at the appropriate scale indicating the regional setting, including but not limited to topography, surficial geology, soil types, vegetation, water bodies and major land use;*
- g) *a description of the site, including but not limited to topography, surface drainage, parent geological materials, soil types, fill material, vegetation, depth to groundwater, groundwater flow direction, adjacent water bodies and land use;*
- h) *a detailed site plan, or photo mosaic or aerial photograph with a 1:5000 scale or finer resolution, indicating major facility areas including waste handling areas and relevant surface features;*
- i) *a summary of remedial actions taken during the last year, where applicable, and a comparison with the detailed schedule in the Soil Management Program Proposal developed as per Sections 3.1 and 3.2;*

#### ***Sampling and analysis***

- j) *a table identifying the affected facility areas, rationale for selection of current sampling locations and sampling procedures, and analytical parameters for each sampling location;*
- k) *the rationale for choosing the sampling procedures and depth-increments when they differ from those specified in Section 2.1;*
- l) *a description of the field QA/QC procedures followed for collecting, handling, storing, and transporting soil samples during the program;*
- m) *the rationale for using the analytical methods and a description of relevant laboratory QC procedures;*

**Results and Discussion**

- n) tables presenting all analytical results for all sampling locations, highlighting values that are greater than any applicable standard specified in Section 2.1.6;
- o) a detailed site plan, photo mosaic or aerial photograph at 1:5000 scale or finer resolution indicating sampling locations where substances of concern exceed applicable standards;
- p) a discussion of analytical results as compared with those of baseline or valid background samples and applicable standards;
- q) an assessment of the need to:
  - i) prevent further contamination;
  - ii) further delineate contamination; and,
  - iii) remediate or manage substances exceeding remediation objectives;
- r) an estimate of the volume of contaminated soil for each area where delineation is complete;
- s) discrete confirmatory samples from the base and side walls of an excavation area as proof of closure of the delineation or remediation;
- t) the location, source and extent of release of any substance of concern resulting from conduct of the Soil Management Program;
- u) a detailed plan of remedial activities for the next year, including any proposed change to the authorized Soil Management Program proposal; and
- v) any other information as requested in writing by the Director;

**Appendices**

- w) borehole logs where a sampling location is drilled;
- x) soil logs for testpit or hand auger sampling locations;
- y) a copy of laboratory data sheets; and
- z) a duly completed and signed form of 'Record of Site Condition'.

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## APPENDIX A: FORMAT EXAMPLES FOR TABLES

The following example tables provide the standardized table format for a *hypothetical* Operational Soil Monitoring Program report. While the table format may depend on the site-specific requirements, Alberta Environment requires it to be easy to read and interpret.



A-1. Example Table for Soil Analytical Results of General, Inorganic and Salinity Parameters

Sampling Location, Depth and Date			General and Inorganic Parameters								Salinity						
Sampling Location	Soil Depth	Date	Texture Class	Clay	Sand	Silt	pH (0.01 M CaCl <sub>2</sub> )	Sulphur (elemental)	CEC	Organic Carbon	EC	SAR	Soluble Sodium	Soluble Calcium	Soluble Magnesium	Soluble Chloride	Soluble Sulphate
Alberta Tier 1 Guidelines, Ind. Fine Surface Soil, 2009			— <sup>1</sup>	—	—	—	6 - 8.5	500	—	—	4	12	—	—	—	—	—
Alberta Tier 1 Guidelines, Agri. Fine Surface Soil, 2009			—	—	—	—	6 - 8.5	500	—	—	2 <sup>2</sup>	4	—	—	—	—	—
Background																	
SL08-04	0.00-0.15	28-Aug-2008	SL <sup>3</sup>	12	68	20	7.4	—	19	0.7	0.44	0.6	18	64	6.8	16	110
	0.15-0.30	26-Aug-2008	L	17	45	38	7.2	—	—	—	0.52	0.8	27	73	8.4	8	160
	0.60-1.0	28-Aug-2008	L	22	50	27	7.1	—	19	1.1	0.60	0.6	23	88	12	6	200
SL08-09	0.00-0.15	27-Aug-2008	L	16	46	38	6.9	—	18	3	0.36	0.5	15	61	9.3	8	70
	0.30-0.60	27-Aug-2008	—	—	—	—	6.4	—	19	0.6	0.24	1.1	24	29	5.9	10	56
	1.0-1.5	27-Aug-2008	CL	30	43	27	7.4	—	21	<0.2	0.27	0.6	16	39	5.7	<5	28
Ponds Area																	
SL08-01	0.00-0.15	26-Aug-2008	—	—	—	—	6.9	4,300	—	—	2.7	0.4	41	570	110	7	1,800
	0.30-0.60	26-Aug-2008	—	—	—	—	6.9	<100	—	—	0.66	2.5	90	75	13	6	240
SL08-02	0.00-0.15	26-Aug-2008	—	—	—	—	7.4	<100	—	—	0.95	0.5	24	150	22	16	420
	3.5-4.0	26-Aug-2008	—	—	—	—	7.8	<100	—	—	0.82	0.5	22	110	32	<5	360
Process Area																	
SL08-06	0.00-0.15	27-Aug-2008	—	—	—	—	7.8	—	—	—	1.7	—	—	—	—	—	—
	0.15-0.30	27-Aug-2008	L	18	45	37	7.6	—	18	0.5	0.41	0.6	17	51	9.1	18	43
	0.30-0.60	27-Aug-2008	—	—	—	—	7.6	—	—	—	0.67	—	—	—	—	—	—
	0.60-1.0	27-Aug-2008	SCL	22	56	22	7.4	—	22	0.3	0.36	1.2	33	40	9.3	19	59

**NOTES:**

Superscript 1: The dotted line (---) denotes no value available.

Superscript 2: The EC guideline for agricultural land use is 2.0 dS/m for topsoil or 3.0 dS/m for subsoil.

Superscript 3: Soil texture class abbreviations: SL for sandy loam, L for loam, CL clay loam, SCL sandy clay loam, following *The Canadian System of Soil Classification* (Soil Classification Working Group, 1998).

Yellow colour denotes values exceeding 2009 Alberta Tier 1 Guidelines for industrial land use, fine surface soil.

Green colour denotes values exceeding 2009 Alberta Tier 1 Guidelines for agricultural land use, fine surface soil.



## A-2. Example Table for Soil Analytical Results of Hydrocarbons

Sampling Location, Depth and Date			Hydrocarbons										
Sampling Location	Soil Depth	Date	Sieve-#200 (>0.075mm)	Benzene	Toluene	Ethylbenzene	Xylenes	PHC F1 (C6-C10)-BTEX	PHC F2 (C10-C16)	PHC F3 (C16-C34)	PHC F4 (C34-C50+)	PHC F4 Gr (C34-C50+)-Silica	Reached Baseline at C50
	(m)	(dd-mon-yyyy)	(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(Yes/No)
Alberta Tier 1 Guidelines, Ind. Fine Surface Soil, 2009			---	0.046	0.52	0.11	15	320	260	2,500	6,600	6,600	---
Alberta Tier 1 Guidelines, Agri. Fine Surface Soil, 2009			---	0.046	0.52	0.11	15	210	150	1,300	5,600	5,600	---
Process Area													
SL02-41	2.0-2.5	30-Jul-2002	44	0.175	0.087	0.422	6.37	44	87,000	410	<12	<1,000	YES
	2.8-3.5	30-Jul-2002	28	0.50	0.15	1.39	20.9	140	2,400	1,800	200	<1,000	NO
SL02-56	0.3-0.6	31-Jul-2002	68	0.37	3.29	2.73	80.9	590	550	800	300	<1,000	NO
	2.0-2.5	31-Jul-2002	20	1.19	4.11	3.79	64.8	710	210	320	280	<1,000	NO
SL08-05	2.0-2.5	27-Aug-2008	34	<0.005	<0.020	2.4	28	200	110	<10	<10	---	YES
	3.0-3.5	27-Aug-2008	---	<0.005	0.49	0.21	3.0	<12	<10	<10	<10	---	YES
SL08-07	0.30-0.60	27-Aug-2008	44	<0.005	<0.020	<0.010	<0.040	<12	<10	<10	<10	---	YES
SL08-08	0.15-0.30	27-Aug-2008	85	0.29	<0.020	<0.010	87	880	970	1,300	620	---	YES
	1.0-1.5	27-Aug-2008	32	37	110	24	450	2,800	1,900	240	<10	---	YES
	2.0-2.5	27-Aug-2008	45	7.1	23	3.8	65	460	350	89	<10	---	YES
	3.0-4.0	27-Aug-2008	---	26	89	8.0	140	670	360	55	<10	---	YES
	6.0-7.0	27-Aug-2008	25	0.36	5.0	0.99	17	170	140	<10	<10	---	YES
	7.0-8.0	27-Aug-2008	---	0.086	0.035	<0.010	0.43	<12	<10	40	<10	---	YES

**NOTES:**

Superscript 1: The dotted line (---) denotes no value available.

Yellow colour denotes values exceeding 2009 Alberta Tier 1 Guidelines for industrial land use, fine surface soil.

Green colour denotes values exceeding 2009 Alberta Tier 1 Guidelines for agricultural land use, fine surface soil.

A-3. Example Table for Soil Analytical Results of Polycyclic Aromatic Hydrocarbons (PAHs)

Sampling Location, Depth and Date			Carcinogenic PAHs							Other PAHs									
Sampling Location	Soil Depth	Date	Benzo(a)anthracene	Benzo(b+j)fluoranthene	Benzo(k)fluoranthene	Benzo(g,h,i)perylene	Benzo(a)pyrene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Acenaphthene	Acenaphthylene	Anthracene	Fluoranthene	Fluorene	Naphthalene	Phenanthrene	Pyrene	
			(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Alberta Tier 1 Guidelines, Ind. Fine Surface Soil, 2009			0.070	---	---	---	0.70	---	7.4	---	0.32	5.0	0.0046	0.032	0.29	0.016	0.051	0.034	
Alberta Tier 1 Guidelines, Agri. Fine Surface Soil, 2009			0.070	6.2	6.2	---	0.60	6.2	7.4	---	0.32	5.0	0.0046	0.032	0.29	0.016	0.051	0.034	
Background																			
SL08-04	0.15-0.30	26-Aug-2008	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	
Storage Area																			
SL08-03	0.00-0.15	26-Aug-2008	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0065	<0.0050	0.0067	0.013	<0.0050	

**NOTES:** Superscript 1: The dotted line (—) denotes no value available.  
Light blue colour denotes analytical detection limit is higher than the guideline value.

## A-4. Example Table for Soil Analytical Results of Trace Elements

Sampling Location, Depth and Date			Trace Element																
Sampling Location	Soil Depth	Date	Arsenic (inorganic)	Barium (non-barite)	Beryllium	Boron (hot water soluble)	Cadmium	Chromium (hexavalent)	Chromium (total)	Cobalt	Copper	Lead	Mercury (inorganic)	Molybdenum	Nickel	Selenium	Thallium	Vanadium	Zinc
	(m)	(dd-mon-yyyy)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Alberta Tier 1 Guidelines, Ind. Fine Surface Soil, 2009			26	2,000	8	2	22	1.4	87	300	91	600	50	40	50	2.9	1	130	360
Alberta Tier 1 Guidelines, Agri. Fine Surface Soil, 2009			17	750	5	2	1.4	0.4	64	20	63	70	6.6	4	50	1	1	130	200
Background																			
SL02-10	0.00-0.15	30-Jul-2002	5.6	143	0.302	0.76	0.16	---	14.7	7.91	9.02	9.8	<0.01	0.38	18.2	0.48	<0.4	19.3	45.1
	0.15-0.30	30-Jul-2002	6.9	131	0.407	0.22	0.08	---	21.6	8.82	12.1	10.6	<0.01	0.26	21.8	0.34	<0.4	24.4	50.2
	0.30-0.60	30-Jul-2002	7.4	126	0.428	0.41	0.07	---	18.5	8.36	12.8	10.6	<0.01	0.23	22.9	0.53	<0.4	21.5	49.3
	0.60-1.0	30-Jul-2002	<1.0	<0.02	<0.05	0.30	<0.05	---	<0.08	<0.07	<0.1	<0.2	<0.01	<0.1	<0.1	<0.3	<0.4	0.0	<0.05
SL02-11	0.30-0.60	30-Jul-2002	4.7	135	0.82	1.08	0.16	---	23.6	6.92	10.1	7.70	0.061	0.38	19.0	<1	0.14	23.3	41.3
	1.0-1.5	30-Jul-2002	5.6	141	0.75	0.30	0.13	---	22.5	7.29	11.3	6.89	0.055	0.47	21.5	<1	0.16	20.1	38.1
	1.5-2.0	30-Jul-2002	5.3	199	0.78	0.17	0.29	---	19.0	7.25	11.2	6.73	0.054	0.53	20.3	<1	0.31	20.2	36.9
Process Area																			
SL02-38	0.6-1.0	30-Jul-2002	6.3	142	0.52	2.4	0.17	0.02	25.0	8.69	19.4	7.66	0.041	0.45	25.7	<1	0.13	34.2	56.5
	1.5-1.8	30-Jul-2002	8.9	263	0.54	0.17	0.18	<0.01	31.7	10.2	20.7	7.55	0.040	0.49	31.7	<1	0.13	35.3	63.0
SL02-39	0.30-0.60	30-Jul-2002	6.1	168	0.44	0.90	0.21	0.01	29.6	6.89	18.5	13.2	0.047	0.97	22.7	<1	0.15	32.5	58.6
	1.0-1.5	30-Jul-2002	7.4	278	0.50	0.12	0.22	0.01	29.2	9.76	19.1	7.34	0.050	0.65	29.8	<1	0.14	35.3	63.0
SL08-05	2.0-2.5	27-Aug-2008	---	---	---	0.90	---	<0.15	---	---	---	---	---	---	---	---	---	---	---
SL08-08	1.0-1.5	27-Aug-2008	---	---	---	0.10	---	<0.15	---	---	---	---	---	---	---	---	---	---	---

**NOTES:**

Superscript 1: The dotted line (---) denotes no value available.

Yellow colour denotes values exceeding 2009 Alberta Tier 1 guidelines for industrial and agricultural land uses, fine surface soil.



